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ABSTRACT

It is proposed that research on neurological organization, cognitive psychology, and artificial intelligence can contribute to understanding the relationship between second language learning processes and academic achievement. Relevant research in these areas and in the field of neurolinguistics is reviewed, with several themes or topics highlighted: the threshold hypothesis of language proficiency; the search for alternatives to this theory; the "connectionist" approach to cognition; the link between learning and attention; the roles of information processing and the visual system in immersion second language learning; and interference effects of sociocultural factors. It is concluded that there are several advantages in trying to integrate emerging information from neuroscientific research, cognitive psychology, and artificial intelligence into educators' thinking about language learning problems: there is substantial research available; data are more precise than in most second language research; the perspective is physical, not behavioral, and information can be constructed from knowledge of the brain's inner workings; and artificially constructed ideas about learning processes can be de-constructed. Contains 55 references. (MSE)

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A NEUROSCIENTIFIC PERSPECTIVE ON SECOND LANGUAGE LEARNING AND ACADEMIC ACHIEVEMENT

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Introduction

In spite of several decades of intensive investigation of a putative relationship between second language learning and academic achievement, no clear picture affording an explanatory mechanism for such a relationship has emerged. The reasons for this are complex, born, it would seem, out of the complexity of the "relationship" itself. What has become clear during the debate is that second language learning can result in a multiplicity of academic achievement outcomes depending on the particular social, economic, or educational circumstances of the learner and, of course, on the learner's aptitude and motivation for learning languages, factors which should not be considered unrelated to those already listed. The combined efforts of researchers thus far have elucidated a dizzying merry-go-round of influences, spinning in close coordination with one another, but never truly interacting. Out of ideological bias perhaps, researchers have insisted on the primacy of one perspective or another, even while acknowledging that no one approach provides a complete explanation of the data. With so much information from so many sources now available on the topic, however, it seems unreasonable and even counterproductive not to make an effort at this point to weave the disparate ideological threads into a cloth which, though it may not be the sole and unique product of combining the strands, will, if care is taken to honour the natural relationships between the individual fibres, constitute a garment of substance and durability with which to clothe the bare "facts". The *raison d'être* for this paper is to attempt to do just that, and, towards that end, it will be posited that it is through the lens of recent neuroscientific discovery on the mechanisms of brain functioning that a synthesis of the varying perspectives can best be accomplished.

An overview of the issues

In the first half of this century, most of the research relating second language learning and academic achievement was aimed at explicating the negative outcomes experienced by educators and learners alike (see Cummins, 1984a, ch. 5 for a comprehensive review of the issues, and Reynolds, 1991, for a detailed list of past reviews). As Reynolds (1991) aptly puts it, "the basic plot line of those early studies" was that "bilinguals (especially bilingual children, the preferred subjects of research), had lower IQ scores than monolinguals, were socially maladjusted, and trailed monolinguals in academic performance" (p. 145). Though these studies have since been proven to be faulty methodologically on many grounds, the perception of the

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second language learner as being at a disadvantage educationally in comparison to monolinguals persists today, in spite of the plethora of studies which, following the lead of the pivotal work by Peal and Lambert(1962), have spoken for a positive influence of second language learning on academic outcomes (see MacNab, 1979; Cummins, 1984a, ch. 5; Reynolds, 1991). Part of the reason for the persistence of the negative perception may be that, as pointed out by Carey (1991a), in spite of the positive data, "the average person is all too familiar with the opposite results: namely, that the immigrant populations and other minority ethnic groups are usually academically disadvantaged while they are immersed in mastering their second language rather than advantaged from working in their non-dominant language, as the additive immersion model would propose " (pp. 340, 341). And, indeed, Lambert later acknowledged that there could be two separate linguistic outcomes experienced by second language learners in immersion situations: "additive" bilingualism, which refers to "the adding on of a second language to a well-developed first majority language", and "subtractive" bilingualism, which implies the "lower vocabulary and oral and written communication capacity in both languages" common to the minority group second language learner's experience (Carey, 1991a, p. 342). In this context, and throughout this paper, a **majority language group** refers to a group whose language enjoys a high status and often, but not always, a high prevalence within a society; a **minority language group** is one whose language has a low status and usually, but not always, a low prevalence within a society.

Such apparently straightforward categorizations, however, draw a barrage of queries from critics of the approach of Lambert and others which seeks to centre the issues in the language arena[1]:

a) How are "bilingualism" and "monolingualism" being defined? Is it possible to eliminate all extraneous variables in "between group" designs comparing monolinguals and bilinguals, and if not, are the results of such comparisons reliable? Can studies of "balanced bilinguals" be meaningfully related to those whose categorization of bilingualism is much broader, or to those which studied children in situations in which the goal of the program was to make them capable of functioning in the second language with no regard as to how they fared in their first language? (MacNab, 1979; Carey, 1987, 1991b, 1993a; Reynolds, 1991)

b) What does it mean to say that a student has "lower" competence in certain language tasks? Against which standards is their competence being measured? Can the circumstances of language use for these students be considered equivalent to those of the students whose performance set the standards? If not, should they be considered deficient in language ability when the language ability which they do develop may be quite adequate to their social needs? (Edelsky et al., 1983; Martin-Jones and Romaine, 1986; Commins and Miramomtes, 1989; Snow, 1992)

c) To what extent does the social status of the first language interfere in the learning of both the first and second languages? What is the relationship between socioeconomic

status and achievement on language tests? (Edelsky et al., 1983; Genesee, 1984; Martin-Jones and Romaine, 1986; Cummins, 1986; Lambert, 1990)

d) Can the research results relating second language learning to academic achievement, whether positive or negative, be considered valid outside of the sociopolitical contexts prevalent during the studies, or do they reflect to some extent at least the image of "political correctness" abroad at the time in the society in which they were carried out? (Carey, 1991a,b, 1993b; McGroarty, 1992)

e) Can the educational treatments given to second language learners in minority and majority situations be considered equivalent even when they appear to be from a resources viewpoint? How do the attitudes towards learning languages and the academic expectations of the students on the part of parents and teachers alter the students' own attitudes and expectations, and ultimately affect their performance? (Troike, 1984; Commins and Miramontes, 1989; Garcia et al.,1988; Hakuta and D'Andrea, 1992; Moll, 1992)

It is evident from the tone of the questions posed that these researchers are arguing from a sociological perspective, and the overarching question which embraces all of their objections is this: If, as has been amply demonstrated by research, social, political, educational, and attitudinal factors can explain much of the variance in academic outcomes seen in different groups of second language learners, why do many second language researchers insist on proposing theoretical constructs which purport to explain the educational outcomes from only a psycholinguistic interpretation of the issues? As Genesee (1984) has noted: "A conceptualization that stresses, or appears to stress, cognitive and/or strictly linguistic dimensions ... will result in cognitive and/or linguistic tests and treatments" (p. 23).

A case in point: the Threshold Hypothesis

As it happens, Genesee was commenting on the work of Jim Cummins, a researcher of the psycholinguistic persuasion whose theoretical constructs have been extremely influential (as well as controversial) in the last two decades. Like Lambert, Cummins is an admirer of Vygotsky's theory of the relationship between language and thought, though it should be noted that he has argued that the theories he has put forward are not incompatible with Piaget's position on these matters (Cummins, 1976). Given this particular psychological bent, it is not surprising that he would see in Lambert's results with immersion students a crucial key, level of language ability or, more precisely, degree of bilingualism, in the unlocking of the mysteries of the variance in academic performance of different groups of language learners. Uncritical acceptance of the sociologically value-laden categorizations of students as suffering "cognitive" advantages and disadvantages as a result of the learning of a second language, categorizations which were later grouped under the headings "additive" and "subtractive" bilingualism, was precisely what led Cummins (1976; 1977) to delineate the **Threshold Hypothesis**, an attempt to explain differential academic

outcomes for second language learners by relating first, the degree of bilingualism of the learners to their cognitive growth, and then cognitive growth to academic achievement. Cummins (1991, p. 76) explains retrospectively the logic behind his proposal of the Threshold Hypothesis in these words:

> Initially (Cummins, 1976), I was concerned with the apparent contradiction between the findings of empirical studies that appeared to suggest cognitive deficits resulting from bilingualism and more recent studies that associated bilingualism with cognitive advantages. Based on the patterns of L1 and L2 development manifested by bilinguals in each of these two types of studies, I suggested that there may be threshold levels of linguistic competence that bilingual children must attain both in order to avoid cognitive disadvantages and allow the potentially beneficial aspects of becoming bilingual to influence their cognitive functioning. The possibility of lower and higher thresholds associated with cognitive disadvantages and advantages was later linked to Lambert's (1975) distinction between subtractive and additive types of bilingual acquisition.

Hence, though studies such as the St. Lambert Experiment conducted by Lambert and Tucker (1972) sought to evaluate the impact of immersion in a second language (in this case French) "on the development of skills in the children's home language, English; on the progress with French; on their competence in the nonlanguage subject matter, mathematics, taught via French; on their measured intelligence and creativity; and on their competence with the sound system of a completely foreign language" (p. 152), in other words, on mainly academic achievement measures, Cummins perceived academic achievement, language proficiency, and cognitive ability as caught up in a tightly drawn relationship and founded his "hypothesis"[2], or, more accurately, his "heuristic", upon this perception. This is particularly evident in a statement made in his text **Bilingualism and Special Education** (Cummins, 1984, p. 107):

> The threshold hypothesis assumes that those aspects of bilingualism that might positively influence **cognitive growth** are unlikely to come into effect until children have attained a certain minimum or **threshold level of proficiency in the second language**. Similarly, if bilingual children attain only a very low level of proficiency in one or both of their languages, their long-term interaction with their **academic environment** through these languages, both in terms of input and output, is likely to be impoverished. (*Emphasis added*)

The paralleling of the relationships between the level of proficiency in the second language and the notions of cognitive growth and academic achievement makes one wonder just how distinct he considers the latter two to be. Certainly, in his later theoretical constructs, there does seem to be a compounding of cognitive growth and academic achievement. This is particularly evident in Cummins' elaboration of the nature of language proficiency, especially in the CALP (cognitive/academic language proficiency) construct,

but also in his conceptualisation of the nature of language proficiency as varying according to positions on two intersecting continua, one measuring the degree of context-embeddedness of the language task, and the other the level of cognitive demands necessary to successfully it carry out. In an explanation of how these variables would interact to "allow the relationships between language measures and academic performance to be predicted for any particular group of individuals", Cummins contends that "[i]n general, the more context-reduced and cognitively-demanding the language task, the more it will be related to achievement" (Cummins, 1984b, p. 15). Thus cognitive demands, academic achievement and linguistic ability go hand in hand in hand, according to Cummins. Given this scenario, it is hard to see where the influence of social variables could find its footing, and it is precisely on this point that several authors have taken him to task.

But does Cummins ignore sociological concerns in his Threshold Hypothesis? Not at all! says Jim Cummins. In a stinging rebuke to those who accuse him of such an oversight, Cummins clarifies his position in these words (Cummins and Swain, 1983, pp. 24, 25):

> The central point made in the paper [Cummins, 1979] is that both research and educational programs must take account of the fact that for both majority and minority students academic outcomes are a function of the **interaction** between educational treatments and what the child brings to school (determined by the societal and linguistic context to which the child was exposed prior to school).

And it must be said that, in his original proposal of the Threshold Hypothesis, he states clearly that "the threshold level of bilingual competence is an intervening rather than a basic causal variable in accounting for the cognitive growth of bilinguals", and goes on to insist that "[a]lthough the cognitive effects of an individual's bilingual learning experiences may be mediated by whether or not he attains the hypothesized threshold level of bilingual competence, the attainment of the threshold is itself determined by more fundamental social, attitudinal, educational and cognitive (e.g. language learning aptitude) factors" (Cummins, 1976, p. 23). To summarise in his own words, then, in his theoretical constructs, "the causal primacy of sociopolitical factors is not in question; however, cognitive and linguistic factors are also of obvious relevance to consider as intervening variables in interaction with educational treatment" (Cummins 1984c, p. 72). The problem is that, as Genesee comments, in spite of his attributing a primary role to sociopolitical factors in accounting for the disparate academic performance of majority and minority group second language learners, "in subsequent discussions of the relationship between language proficiency and academic achievement, these social foundations are virtually ignored" (Genesee, 1984, p.21).

Though, as noted above, there are many grounds for questioning the heuristic value of the Threshold Hypothesis, not the least being the elusive nature of the "threshold of bilingual competence" (see Cummins, 1976, p. 24, and 1991, p. 85), Genesee pinpoints what is, in my opinion, the major flaw in Cummins' reasoning. The Threshold Hypothesis, as well

as the theoretical concepts constructed thereupon, is conspicuously lacking in sociological variables. Yet, in an effort to test the validity of the Threshold Hypothesis using groups of students at different stages of bilingual competence, Diaz (1985) discovered that "the observed cognitive differences between second-language-proficiency groups can be attributed to group differences in socioeconomic variables" (p. 1376).[3]

The outstandingly thorough and clearminded analysis of the research relating cognitive growth and bilingualism carried out by Reynolds (1991) only adds fuel to the fire. The conclusion he came to was this (p. 159):

> Due to the prevalence of design problems and other logical difficulties I have described, the central question we should be asking ourselves is not whether the thesis that bilinguality affects cognitive performance is true or whether the reverse is true, but whether there is a relationship at all.

A quest for alternative answers

So, where does all of this leave us? Is it 'back to the drawing board' for a fresh start? As my Scottish ancestor Hume might have replied "Maybe aye, and maybe, och aye!" (Roughly translated as "Who knows?") To my mind, there are two important considerations to take into account in our deliberations on the Threshold Hypothesis. First, the data upon which the Threshold Hypothesis was founded must be regarded as suspect not only on methodological grounds, but also on sociopolitical grounds. The Peal and Lambert study and others purporting to find positive relationships between cognitive ability and bilingualism were born in a Canada whose government was determined to pursue a policy of Bilingualism and Biculturalism, and in which there were federal funds aplenty for immersion education programs (Carey, 1991a,b, 1992, 1993a,b). In order to attract anglophones (the majority language group in all provinces except Quebec) to French immersion programs, therefore, "it was critical to demonstrate that students would be able to master French without sacrificing academic achievement" (Carey, 1991a, pp. 335, 336). It has become clear in recent times, however, that there is an academic price to be paid for studying in a second language, especially in the senior school years (Carey, 1991a,b, 1993a). Just as the Canadian perspective on the issues surrounding bilingualism has been coloured by the political imperatives of the society, it is highly likely that the English only movement in the United States has contributed significantly to the climate of negativism that dampens enthusiasm towards bilingualism in that country (McGroarty, 1992). In retrospect, therefore, it seems somewhat naive on Cummins' part to have accepted the research data which formed the basis of his thinking on these matters at face value, especially when education itself has long been recognised to be a profoundly political enterprise.

Secondly, and even more importantly in my opinion, there is this problem of "cognition": How is it defined? What does it mean to say that a child is "cognitively" advantaged or disadvantaged? Are these "cognitive" advantages general or specific to a particular task?

Neither Cummins nor any of the other researchers talking of such variables defines what it is they are discussing, at least, not in any of the papers I have read. Certainly, they give details of the tests they are using to measure it: Reynolds (1991), who like MacNab (1979) questioned what was being considered under the rubric of the "dependent variable" in many of these studies, has collated a sampling of no less than 15 intelligence tests, 3 divergent thinking tests, 6 visual-spatial tests, and 12 "other" tests (p.160). The very existence of such a large and diverse group of measures provides evidence of the lack of consensus in the research community as to how cognitive performance can best be gauged. And, even if the complete tests were considered adequate measures of cognitive ability, in many of the studies into the relationship between cognition and bilingualism, only one or two subtests out of the test kits are used. For example, Cummins (1977) used "two subtests of the Kuhlmann Finch Intelligence Test designed to measure verbal ability (subtest 1) and general reasoning (subtest 4)" and the "Utility Test from the French, Ekstrom and Price (1963) Kit of Reference Tests for Cognitive Factors" as cognitive measures; Diaz (1985) measured analogical reasoning by means of "a modified version of the Stanford Binet Intelligence Scale subtest of opposite analogies", and administered "the Raven's Coloured Progressive Matrices (CPM) and the visual-relations subtest of the SRA Primary Mental Abilities Test (Grades K-1)" as measures of nonverbal abilities. It is impossible to resist the temptation of asking of these researchers the question crooned by Peggy Lee in her famous song: "Is that all there is .... to cognition?"

In a search for some insight into this issue, it is instructive to examine what might be considered the least technical definitions of the terms "cognition" and "cognitive", those to be found in a common dictionary such as Webster's (1991):

> **cognition:** 1. the act or process of knowing: perception. 2. something known or perceived.
> **cognitive:** 2. of or pertaining to the mental processes of perception, memory, judgement, and reasoning, as contrasted with emotional and volitional processes.

Perception, memory, judgement, reasoning! At this very moment, armies of neuroscientists and cognitive psychologists across the globe are carrying out research in an effort to gain some understanding of the fine structure of these processes, and they themselves are reluctant to give definitions of terms such as cognition[4] due to the inadequacy of their knowledge of the underlying processes. It seems a mite cavalier, therefore, on the part of educators to be bandying around the designations "cognitively advantaged" and "cognitively disadvantaged" in descriptive and prescriptive ways.

A close reading of some of the educational literature addressing the topics of cognition and cognitive ability or growth reveals some of the confusion that surrounds these concepts in this field. Cummins portrays cognition as being made up of an inner core of "basic cognitive abilities" and cognitive abilities that are susceptible to environmental influences especially through the mediation of language (see Cummins, 1976; 1979). What evidence

does he have to support a division of this type? How is he defining "basic cognitive abilities"? Critiquing Cummins' work, Martin-Jones and Romaine (1986) comment that he "appears to be equating semantic development with cognitive development" (p. 29) in his definitions. Are they suggesting that semantic development is not cognitive? In another criticism of Cummins' proposals, Genesee (1984, p. 21) notes that "current approaches in social psychology stress the notion of social **cognitions**". Is his use of the term "cognitions" here in keeping with the definition above or does he mean "bodies of knowledge"? MacNab (1979), in his otherwise insightful paper on "Cognition and Bilingualism", employed the terms "cognitive knowledge", "cognitive learning", "cognitive ambiance". What do they mean? Can it be said that there is knowledge which is not cognitive? How does "cognitive knowledge" differ from "cognitive learning"? MacNab states that "[c]hildren who become bilingual in additive environments tend to come from homes where there is an open cognitive ambiance and where there is encouragement of learning in general and language learning in particular" (p. 251). But does learning not go on in every environment? Is there ever a time when one is not learning, with or without encouragement? And if learning is going on, is the activity which promotes it not cognitive?

Edelsky et al. (1983) deplore the fact that, in his claims for cognitive advantage or disadvantage, Cummins makes use of data which are dependent on tests which "fail to illuminate the cognitive processes they claim to assess, focusing as they do on answers rather than processes", protesting further that "almost none [of the tests] investigates cognitive functioning from a broad theoretical framework of cognition" (p. 7). While corroborating the spirit of this critique in his analysis of the available data on the cognitive consequences of bilingualism, Reynolds (1991) directs it more generally at the second language research community:

> In terms of working towards a model of cognitive benefits, we've been acting like Stephen Leacock's character who "flung himself upon his horse and rode off madly in all directions"; we have no theoretical focus. (p. 164)

He then goes on to discuss the theoretical approaches developed thus far and to recommend Sternberg's Triarchic Model of Intelligence as being the most promising candidate for directing future research. My approach to this issue, however, is to question whether we should get embroiled in it at all. In her ruminations on cognition, neurophilosopher Patricia Churchland (1986, pp. 151, 152) has stated:

> Learning and memory are at the dead center of cognition, if anything is, and as their categories are revised and redrawn, the theoretical landscape of higher functions is undergoing tremendous transformations. The general category of learning has already fragmented into a variety of kinds of process, and indeed the term "learning" is now often replaced by the broader and less theoretically burdened expression "plasticity".... Whether these [distinct manifestations of plasticity, including so-called "higher" and "lower" learning processes] involve common or

> distinct mechanisms, and how many distinct processes there really are, remains to be discovered. Whether anything like an **empirically justified** distinction between the cognitive and the noncognitive will survive, or if it does, whether it will confirm even a rough approximation of our current hunches, also remains to be discovered.

On this view, therefore, the designations of processes as "cognitive" and "noncognitive" may prove to be completely groundless from a **brain-oriented** perspective. Given this uncertainty, it would seem propitious to side-step the issue of "cognitive" advantages and disadvantages on the grounds that the degree of resolution of any "cognitive" approach is too low, and perhaps even completely misguided conceptually, to be of use as an analytical tool in resolving the problems encountered in second language learning. My contention is that an alternate and potentially highly insightful perspective can be gained by considering the issues through the lens of a theory which focuses on understanding the plasticity or **learning capability** of the brain, human and non-human, the theory of **connectionism**.

This is not so radical a step as might be supposed: connectionism is in its essence an information processing theory of the type espoused by Cummins in his clarification of the nature of language proficiency (Cummins, 1984b), and, of course, by McLaughlin (1983, 1987), and Reynolds (1991). What is different, and, in my opinion, superior, about connectionism is that it provides a more detailed accounting of the **mechanisms** by which the brain processes information, an accounting which Edelsky et al. identified as missing from Cummins' theoretical explanations of the "facts", and the lack of which Cummins himself appears to regret in one of his most recent papers touching on the Threshold Hypothesis (Cummins, 1991, p. 86). Since my intent is ultimately to offer an alternate explanation of the data which gave rise to the conceptualisation of the Threshold Hypothesis, the aspects of the theory of connectionism which will be outlined will be only those which are most pertinent to an understanding of the processing of information in the brain. And since all concerned appear to be agreed on the necessity of a theoretical perspective which will shed some light on the interaction of social and linguistic variables in the determination of academic achievement, the explanation offered will attempt to clarify how a non-linguistic factor such as the social status of a language might "get inside the head" of a learner to influence how well a language, first or second, is learned.

A crucial premise of my argumentation will be that no one influential variable will have primacy in the determination of academic outcomes in all situations, but rather that the weighting of the importance of each interacting variable will change from situation to situation, as well as from individual to individual. It will be proposed, nevertheless, that some generalities in behaviour will occur due to the fact that the human brain will react in certain predictable ways given a particular set of environmental circumstances.

Connectionism: some essential concepts

Connectionism has been described by Paul Churchland (1989, p. 130) as "a recently developed theoretical and experimental approach to the phenomena of human cognition that is at once (a) naturalistic, (b) reductionistic, and (c) capable of explaining both the radical plasticity of human consciousness, and its intricate dependence on the extended cultural surround". It is an approach which, again in Churchland's words, "resides at the interface of computational neuroscience, cognitive psychology, and artificial intelligence". The most compelling aspect of connectionism for the educator is its ability to provide some illuminating insights into the processes of learning, insights which are solidly founded on empirical studies in the three fields listed above. The relationships within this triad can be described in simple terms as follows: cognitive psychology deepens our understanding of the behavioural phenomena to be explained; computational neuroscience studies how the neurons, the basic units of the brain, when given a certain sensory input pattern, integrate the information and compute an output which initiates a specific behaviour; artificial intelligence uses information obtained from neuroscientific studies to build "biologically valid"[6] models of brain systems (e.g. the visual system) to see if behavioural tendencies observed in humans (and other animals) can be reproduced. When they are reproduced successfully, it can be concluded that the model must mimic to some degree the connectivity of that same system in the brain itself and hence knowledge of the modus operandum of that system has been gained.

The research to date on the basic architecture of the brain has confirmed that the brain is a massively parallel information processor. As a general rule, it is constructed of neural networks consisting of several (typically between 5 and 50, according to Churchland) interconnected levels of neurons which work together to process raw sensory input signals into output signals which can then be passed on to other areas of the brain. On each level of the network, the input is processed in parallel, that is, simultaneously, and the output signals of each level are passed on to the next. This kind of processing is extremely fast as the time necessary to complete it is determined solely by the number of layers (or levels) in the network. The final result of the output signals could be as diverse as the initiation of an action, an eye movement, for example, or the stimulation of an emotional reaction, or recognition of an object, or a creative thought. A characteristic of the brain which is worthy of note is its enormous degree of connectivity. Not only is there a high degree of interconnection between neurons on different levels, but there is interconnection within levels, between networks within subsystems, between subsystems within a major system, between major systems, and even between hemispheres. It is only a slight exaggeration to say that, in the brain, everything is connected to everything to a greater or lesser degree! Hence, the name of the game played by the neurons is integration of information through computation. (For details on how neurons compute, see P.S. Churchland, 1986; P.M. Churchland, 1989; Churchland and Sejnowski, 1992; Kosslyn and Koenig, 1992; these texts treat the topic in different ways and to different degrees of specificity.) What is happening during the computations is that neurons are "talking to each other", and, unlike in many of the models of neuronal activity, the conversation is not one way. Though the chain of information processing will most often start off from the periphery (from the neurons most closely connected to the sensory organs), stored

information from neurons more distant from the periphery can be passed back to the sensory neurons through "recurrent" or "reentrant" feedback loops and can thus affect the outcome of the processing. A prime example of a visual feedback effect is found in the Kanizsa Triangle illusion (Zeki, 1992), in which a triangle is seen, even though it is not specifically represented, due to the feedback to the primary visual cortex from areas of the brain which have stored knowledge of the concept of a triangle. Here, then, we have an example of learning (that is, what might traditionally be called "cognitive" information) affecting perception, and it is but one of the many which could be cited.

The importance of this general interconnectivity and integration of information for educators and for the purposes of this paper is twofold: first, since stored information in the brain is capable of having an effect on what we perceive at the most fundamental level, it seems highly probable that it is also capable of affecting what we learn; second, given that integration of information from the various sensory systems does occur, and, moreover, is often necessary for the adequate completion of a task, for tasks which do require such integration, changes in the information processing abilities of one system could have an effect not only on the final output of the computation, but on the information processing capabilities of other systems contributing to it. This will be elaborated upon below.

Learning and attention

Despite the fact that the more general term "learning" covers a variety of distinct mechanisms through which the plasticity of the brain manifests itself (for some examples see Kandel and Hawkins, 1992, and Shatz, 1992), there are some general principles about learning which can be abstracted from the various instances. On the connectionist view, learning is a physiological event which is characterised at the neuronal level by relatively long-lasting changes in the strengths of the connections between individual neurons. These changes will only occur, however, if there is a confluence of facilitatory inputs from other neurons in near and distant areas of the brain on the cell receiving input[8]. Once effected, the changes in connection strength are subject to further change depending on the characteristics of any new input to the cell. Thus learning can be reinforced or eroded.

The changes in connection strength are most readily accomplished if **attention** is accorded to a selected portion of incoming sensory input. It should be noted at this juncture, that "attention", as it is studied by attention researchers, is a highly complex construct which bears only a passing resemblance to the concept of attention held by most educators (see Enns, 1990). Although extremely difficult to define (see note 4), for the purposes of this paper, attention will be characterised as a facilitatory mechanism for the selection and processing of information. The **attention system** of the brain is regarded as an important central brain mechanism for the promotion of the types of changes in connection strength involved in learning (Singer, 1990, p.224). It has recently been shown through Positron Emission Tomography (PET scan) studies of language processing that

there appear to be two separate and complementary anatomic circuits subserving the processing of information in new tasks (designated "novel" and "naive" situations in the study) and in practised tasks (Raichle et al., 1993). According to these authors, "under normal circumstances fluent speech is a blend of the activities of the two circuits 'in which we are aware of the sense of what we are saying, rather than of every word we say' (Lichtheim, 1885)". These systems, therefore, could very well reflect the controlled (attention demanding) and automatic (less attention demanding) processing dichotomy identified in earlier information processing theory through more conventional research methodologies. Though the subtractive methods employed at this level of PET scan technology has been roundly criticised by many, it does gain credibility when the results confirm the conclusions arrived at by other research paths. An extremely interesting find in the study is that when one system is switched on, the other is off. In a public presentation of the paper, Petersen (one of the authors) noted that this suppression of activity in other areas when one area of the brain is "spotlighted" by attention is a common phenomenon. He and the group at Washington University have found, for example, that "doing an intensely visual task causes deactivation of auditory and somatosensory cortex"[7]. In keeping with these findings, other attention researchers have concluded in general that, even down to the cellular level, attention produces a benefit at the attended location, but has costs at the unattended location[8]. All of this only confirms the insights of the great psychologist William James who is quoted as saying that "To attend to one thing...'implies the withdrawal from some things in order to deal effectively with others' (1890:404)" (Cited in McLaughlin et al., 1983, p. 136).

Implications for education

Why should any of this interest the educator? Well, what these findings imply is that when attention is tightly focused onto one processing system in the brain, learning can go on there at an enhanced rate. However, while learning is going on in the area under the influence of attention, it will be repressed in other areas of the brain. Now, for the student who understands and produces fluently the language used in the classroom, attention should be moved from one sensory system to another on the basis of which system is currently receiving information most pertinent to the solution of the problem at hand. [Note: the normal switching of attention can be driven involuntarily (dependent on the saliency of the input), voluntarily (for example, to match current expectations or goals), and, to some extent, by past experience[9].]

Hence, no one sensory modality should be strongly favoured as the most efficient way of processing information, although some imbalances will occur naturally as a function of "cognitive" style, or, what I prefer to call, **information processing style**. Throughout this paper, information processing style will mean the particular preferences exhibited by an individual for gathering and processing information by means of certain sensory systems, and given the premise of connectionism that the plasticity of the brain is dependent to a very large degree on "the extended cultural surround", it is posited that, though information processing style itself will be determined in part by predispositions innate to the individual learner, it will also depend to a significant degree on experiential history. For example, in

a culture whose survival is tied to an ability to discern visually minute variations in the environment, high visual acuity will develop due to the attention given to the visual system. Thus, in general, the information processing style of the members of such a cultural group would be tuned to favour the visual system. This is not to say that the auditory system or the somatosensory systems, the other major information gathering systems, would be ignored. Nevertheless, preferential processing by one system could easily develop in accordance with environmental demands given the plasticity of the sensory systems.

What has been suggested by the above argumentation, then, is that the weighting of the attentional preference shown to one sensory system over the other will be partially, at least, a function of the **meaningfulness** of the information gathered by each system. This notion has considerable support from attention research, although the terminology used to represent "meaningfulness" is inconsistent. For example, it has long been noted that "[a]ttention seems to be often a function of [stimulus] cue **value**, not merely cue strength" (Moray, 1969, p. 171). Moray refers readers to an exceedingly clear elaboration of the sense of "cue value" in the theory of Deutsch and Deutsch (p. 33). They point to the findings that the "importance" of the signal to the organism is a strong determining factor in the capturing of attention, and that "the importance weighting is a function of past experience". Thus, it can be said that the meaningfulness (or value, or importance) of a cue is a function of how well it has been learned, that is, of its familiarity[10]. Though this work is relatively old, it is fascinating to note that, even in artificial intelligence research, the benefits of incorporating "values" into the neural architecture of robots has been clearly recognised (Edelman and Reeke, 1990, p. 235):

> In constructing Darwin III, we found very early on that the machine wouldn't work unless we put in **values**, i.e., a set of simple evolutionarily constructed innate goals for the organism, such as, for example, **seeing is better than not seeing**.... these value-sensitive cells don't tell the organism **how** to do anything, they just evaluate after something is done whether the net effect of the action was of value for that organism or not.

Hence, for artificial "brains" as well as natural ones, assessing the meaningfulness of the outcome of a decision initiated by information processing is valuable in the development of intelligence, and, of course, the process of evaluation presupposes a reference file which must be experience-informed, whether innately programmed or no. In neurocomputational terms, these value-sensitive cells would appear to perform the function of a "teacher" or recurrent loop which would provide feedback to alter the pattern of connection weights (see Churchland, 1989, pp. 243-250).

How, then, might experience function in the capturing of attention? In recent times, competing theories have been proposed to explain the mechanics of attention in visual search (see Cheal and Lyon, 1992). One of them, the Guided Search Model, proposes that the early parallel stage of information processing produces an "activation map" within the visual system which guides the later serial stage (see also Treisman, 1988, and Koch and

Ullman, 1985). The parallel stage of processing is the fast automatic stage which needs very little attention, and the serial stage is the slower attention demanding stage. Thus, according to this model, what is given focused attention appears to be determined by what has been processed more quickly, at least in the early stages of visual processing. What is interesting about this particular model, is the reverberation that it sounds with the work done by the Washington University group on the processing of "novel/naive" and "practised" language tasks. In both cases there is a fast, less attention demanding process, and a slower attention demanding process. And given that, during its early developmental stages, the visual system itself is highly plastic and continues to exhibit plasticity even after the critical period (Bear et al., 1987), experience must contribute to its processing ability in some way. In elaborating her Feature Integration Theory of visual perception, Treisman (1988) has also made reference to the possible role of plasticity in the defining of visual "features" (see also note 9). Is it possible then, in accordance with the work on the processing of language tasks, that, even in the visual system, the fast parallel stage is itself determined by experience, and that it is essentially experience (or learning, or stored knowledge) which guides attention in the slower serial stage of processing? This would certainly seem to be the case in the Kanizsa triangle illusion mentioned previously.

In trying to make sense out of this data on attention and learning, a daunting task for even the best informed, certain confluences in the findings on information processing seem worth noting:

1. There do appear to be two separate routes or stages in information processing in a particular system, with one being faster than the other. The fast route appears to be capacity unlimited and less demanding of attention, while the slower route is capacity limited and more attention demanding.

2. Experience or learning appears to be a determinant of which route input is processed by. Input which is already familiar to the organism appears to be processed more quickly than unfamiliar input.

3. It is possible that the fast route has some control in selecting which features of the input receive focused attention.

Considering these three points (tentative as they may be) and the fact that learning and memory are dependent on the sensory systems for information gathering, it seems logical to propose that it is a general truth of information processing in the brain that what has already been learned will determine to some degree what will be learned in the future. In other words, it seems reasonable to propose that the acknowledged meaningfulness of previous learning will be a determining factor in what the brain will perceive as being of further value, and that it will do so by means of the "capturing" of focused attention. Furthermore, since what is of value or is meaningful is closely related to what is familiar, **sociocultural values** should be important in determining what is learned. Though this

should hold true of all learning, it is hypothesised that it will be particularly so in the specific instance of language learning, since language is extremely important to and integrated with cultural identity and its concomitant values. Some, the "language is culture" advocates, would go so far as to say the two are indissociable.

Turning attention towards the second language learning process

A consequence of the information processing scenario outlined above is that, due to the limited capacity of the attention system charged with the processing of new information, processing capacity can easily become overwhelmed in situations in which a high percentage of the incoming input is unfamiliar. This is important for second language learners, especially in an immersion situation. As McLaughlin et al. explain (1983, p. 137):

> If, for example, one is exposed to a rapid flow of speech in a language one does not know, the effect is that information-handling capacity becomes overloaded and one eventually "switches off."

However, what "switches off" may be the allocation of attention to the auditory system only, freeing up the limited-capacity attentional system to focus elsewhere for information gathering, most probably to the visual system, the other major information gathering system in humans, but possibly to the somatosensory system, or to personal reflection, normally referred to by teachers as "daydreaming". And, following the argument detailed above, it may be that the familiarity of the visual information, which is almost certain to be closely related to the past experience of the learner cultural differences notwithstanding, will guide attention towards the visual system and away from the auditory. (Culturally related effects will be broached later in the discussion.) Hence, in a situation of language immersion, attention could become tightly focused on the visual system. If it does, it will suppress the activity in other sensory systems thereby enhancing learning through the visual system while reducing learning through the others until such time as the information overload of the auditory system rectifies itself. Since second language research data suggest that at least two years is necessary to master the most basic aspects of a second language (Cummins, 1984a, ch. 6; Collier, 1987, 1989), it is likely that information gathering through the visual system will continue to be of increased importance for the second language learner for some years, particularly in immersion situations.

So far, however, the hypothesis proposed is based only on a logical piecing together of data and theory taken from several disparate disciplines, and the question that begs to be posed is this: "Is there any evidence for an increased reliance on visual information gathering and/or for a consequent suppression of auditory processing in second language learners?" I believe that there is, and propose to present it forthwith.

Evidence for the development of a bias towards information processing via the visual system in second language learners in immersion situations

a) **The *Age and Rate of Acquisition of Second Language for Academic Purposes* study by Virginia Collier (1987)**

This study "analyzed the length of time required for 1,548 advantaged limited English proficient (LEP) students to become proficient in English for academic purposes while receiving instruction in English in all subject areas" (p. 617). This was an American study which was intended to test the validity of the BICS/CALP dichotomy of language proficiency proposed by Cummins, and its general conclusions supported Cummins' theorising. One very interesting outcome of the study was the finding that LEP students did extremely well in mathematics. Collier noted that "Math achievement of ESL graduates in the 11th grade was much higher than 11th grade achievement in other subject areas, reaching above national averages (53rd-59th NCEs) but still lower than 4th-, 6th-, and 8th-grade LEP students math achievement" (p. 631), and later commented:

> It is encouraging that advantaged LEP students can perform so well in mathematics, even when portions of the exam include math concepts and problem solving, which rely more heavily on language skills. Although the remarkably high mathematics achievement was the exception to other content-area achievement, ESL graduates' scores still followed the same pattern as that found in the other four content-area tests (p. 637)

To my mind, the most interesting feature of the results in mathematics was the correlation in the pattern of the results across all grades (with the slight exception noted for the 11th grade). Not only were the math results far higher than the results in other areas for all grades as Collier remarked, but for the 4th, 6th, and 8th grades the scores were at their highest average for the students with the shortest length of residence (LOR), 1-2 years. Furthermore, as the length of residence increased, the average scores slowly dropped, while still remaining far above the scores achieved in other subject areas (p. 629). Hence, this is a pattern which seems to cut across age groups.

What I am proposing as an explanation of this correlated patterning of results is first of all, that, during the beginning stages of their residence in a new country, the students develop a heightened sensitivity to information arriving through the visual system due to both the overloading of auditory system processing and the familiarity of the visual input in the environment, and second, that mathematics, with its dependence on universally recognizable concepts manipulable through **visual** symbols, is particularly suited to analysis by means of visual system processing. To speak to Collier's comments with respect to the necessity of some language skills in problem solving, the amount and type of language used in mathematics problems tends to be very limited and would be easily learned given adequate motivation, and furthermore, the practised knowledge of the mathematics concepts and terms would reduce the information processing load freeing up the high attention, limited-capacity information processing system to tackle both the language and the particular mathematical concepts involved. Furthermore, it is intriguing to note that the content area chosen by Lambert and Tucker in their 1972 immersion study

was mathematics precisely because it was a "nonlanguage subject matter" (p. 152). In their summary of the findings on the grade 2 classes, they commented:

> What was particularly interesting about the comparison was that the Pilot and Follow-up Experimental Classes scored as well as the English controls on problem arithmetic and significantly better on computational arithmetic. (p. 105)

That the experimental classes did better than the English controls in computational arithmetic would have been predicted by the premises outlined above, that is, that mathematics, especially the language reduced components, is a content area which is easily analyzed visually, and that second language learners develop a heightened capability to process information by means of the visual system.

b) **The nature of the "cognitive" tests commonly used for second language learners**
In his analysis of some of the reasons why "minority" students tended to be seen as underachievers, Cummins (1984a, ch. 2) questioned the validity of the various WISC-R subtests for these students, and commented on the patterns of results in these words (p. 24):

> Several things emerge clearly from the patterns of WISC-R subtest scores. First, students perform much closer to the average range on Performance as compared to Verbal subtests. There is relatively little variation among Performance subtests... Arithmetic and Digit Span appear to be somewhat less culturally/linguistically biased against ESL students than the other Verbal subtests.

A closer examination of these performance tests shows them all to be tests dependent on visual processing: picture completion, picture arrangement, block design, object assembly, and coding. Hence students who have adopted an information processing strategy which favours the visual system could be expected to perform better on these tasks. And, of course, on the basis of the argumentation detailed above, arithmetic and digit span would be easier for these students than other verbal subtests. Thus, though Cummins attributes the difference in scores to the fact that some tests are "culturally/linguistically" biased against ESL students, the information processing demands of the tasks may be an equally important explanatory factor.

As a further instance of the importance of considering information processing demands, an alternate explanation for the low scores on verbal subtests for ESL students may be that, due to an increased allocation of attention to visual processing, the processing of auditorily presented information is suppressed. Some anecdotal evidence supporting this interpretation can be found in comments made by both teachers and psychologists describing the performance of students recommended for psychological testing (see Cummins, 1984a, ch. 2). Many of the descriptions cited made reference to low verbal abilities as compared to nonverbal, and a few made specific reference to problems with auditory memory:

1. "He speaks Italian fluently and English well.... His attention span is very short. He is always very easily distracted. His auditory memory and discrimination skills seem to be below average but his visual memory is better, and his visual discrimination skills seem to be fairly good." (p. 33)

2. "While she is progressing in English, she is still behind, resulting in a low overall verbal score. Performance (score) was within the average range and this may well be a measure of the girl's potential.... No real disability is obvious other than auditory memory and a rather impulsive manner of attacking her work." (pp. 52, 53)

3. "His only strength was speed in copying designs. His auditory memory is quite weak which may be holding back his English development." (p. 54)

Since only a small number of excerpts from the referral and testing documents were cited, it would be interesting to find out just how representative these findings with respect to auditory memory and discrimination difficulties are, as they may be indicative of the fact that the root of the "linguistic" problems for these students lies in a reduced ability to process information auditorily.

Precisely because of the possibility of "linguistic" demands biasing test results, many researchers use "nonverbal" measures of "cognitive" ability for assessing second language learners. As Reynolds (1991) points out, although there are a number of different tests available, some of them are "used much more frequently than others, for example the **Peabody Picture Vocabulary Test** and the **Coloured Progressive Matrices**" (pp. 159, 160). Closer examination of just one of these, the Coloured Progressive Matrices (CPM) test shows that, apart from an initial verbal explanation, no language knowledge is necessary to complete the tasks since they are based on the matching or completion of visually presented patterns. Reynolds (1991) notes that the best correlation between this test and the Wechsler Preshool and Primary Scale of Intelligence is found with the Picture Completion subtest (.43), and that "[b]ecause a respondent can adopt either a verbal/analytic[11] approach to the test or solve the matrices through visual perceptual discovery, this is not a 'pure' test" (p. 161). The fact that many of the claims for "cognitive advantages" for second language learners have been based on this test is interesting, therefore. Any putative "advantages" that may be emerging may simply be an ability to process information more efficiently through visual information gathering. Hence, whether this constitutes an "advantage" or not rests on the characteristics of the task to be analysed.

c) **A study by Rafael Diaz on "Bilingual Cognitive Development"**

A prime example of a study which claims to have discovered "cognitive" advantages for ESL students based in part on CPM results, and one which relates to the debate on the Threshold Hypothesis proposed by Cummins, is that conducted by Diaz (1985). In this research, Diaz was specifically interested in testing the effect of degree of bilingualism on cognitive ability, as well as exploring the cause-effect relationship between the two.

Arguing from the logic of the Threshold Hypothesis, he made the following hypotheses:

> As suggested by previous research findings, it was hypothesized that there exists a positive relation between degree of bilingualism and cognitive ability for those children possessing relatively high second-language proficiency. No relation or a negative relation was expected for children of low second-language proficiency. It was hypothesized also that degree of bilingualism at time 1 would predict cognitive abilities at time 2, supporting a cause-effect model in which degree of bilingualism is the causal factor affecting children's cognitive abilities. (p.1378)

The groups of Spanish speaking children (ages 5-7, in kindergarten and grade 1) which he chose were divided into lower English proficiency (LEP) and higher English proficiency (HEP) cohorts, in which the majority of the LEP children were able to produce "only isolated English words" at the beginning of the year, whereas the HEP children "could produce complete English sentences but only few with correct use of prepositions and verb tense" (p. 1378). It was noted later that the HEP group had been resident in the United States "much longer" (p. 1381).

Tests of "cognitive ability" were administered to the children on two separate occasions, one at the beginning and one at the end of the school year, and consisted of one subtest of analogical reasoning, three of metalinguistic awareness, two of spatial awareness, and the CPM test. The results were indeed interesting and complex. However, for the purposes of this paper it suffices to report that there was support for the contention that bilingualism is causal in its effect on "cognitive ability", and that, within both the LEP group and the HEP group, English proficiency at time 1 predicted significant portions of the CPM test performance at time 2 ($p<.001$ and $p<.01$ respectively). In his summary, Diaz calls attention to the fact that this predictive ability of degree of bilingualism is stronger for children who have less rather than more knowledge of the second language as was forecast by Cummins' Threshold Hypothesis. He ponders the reasons for this relationship in the closing remarks (p. 1387):

> The present findings lend some support to the claim that bilingualism fosters the development of cognitive abilities, especially during the initial period of second-language learning. These findings, although important, are only a first step in understanding the issues at hand. The question remains as to **how** bilingualism affects cognitive abilities, especially when cognitive ability is measured by performance on nonverbal tests such as the Raven's Progressive Matrices [CPM]. (p. 1387)

In answer to his own question, Diaz later developed an explanatory model of the interaction between bilingualism and cognitive development (Diaz and Klinger, 1991). To that same question, however, I would respond that, for students newly immersed in a language, the propensity to depend on the visual system for the processing of information is much higher than for those students who already have a working knowledge of the

language. As a result of this, their scores on a test such as the CPM which, I have argued, assesses their ability to analyse problems visually would be only indirectly related to their degree of bilingualism. The postulated "benefits" which are observed would then come about in the following way : the low level of ability in the language causes an increase in attention allocation to the visual system, and this in its turn causes an apparent increase in "cognitive" ability, **if this is measured using tests dependent on visual analysis of tasks**. The boost should be only temporary, since the gradual increase in language ability will temper the attention effect, and slowly but surely attention allocation should return to a more normal balance between the auditory and visual systems. Whether it will return to its previous balance, however, may be subject to other influences including the prevailing political climate, as will be argued below. The tapering off of the heightened dependence on information processing by visual means observed for higher English proficiency groups, therefore, would give rise to the low English proficiency "threshold" effect hypothesised by Diaz (p. 1386).

What I am suggesting, of course, is that the observed "cognitive advantages" are evidenced because of how cognition and advantage have been defined by the test, and are therefore circular in their conception and unhelpful in their explanatory power.

Relevance of the explanatory power of the neuroscientific perspective for second language learning and academic achievement

Though the evidence presented is by no means conclusive, it does lend some support to the contention that second language learners in immersion situations develop an increased dependence on information processing via the visual system, and that this leads to both an enhancement of the ability to learn through visual analysis of tasks, and a suppression of information processing ability via the auditory system. Why is such an insight important?

Its importance stems from the diagnostic insight it gives into information processing problems. Given the integrative nature of brain processing, any alteration in the balance of the contributions of the various sensory modalities will have repercussions on what is learned, and how well that learning is encoded. Knowing which systems are likely to be affected under certain environmental conditions, therefore, gives clues as to which kinds of difficulties may occur at the behavioural level. An imbalance in visual and auditory processing, for example, would predictably have an effect on language skills such as reading, which has been shown to depend on information processing via both the auditory and the visual systems. The initial visual input stimulates processing in two distinct routes, called the phonological system and the semantic system by some (Hinton et al., 1993). However, both routes interconnect with the "semantic system", the difference being that the phonological route makes use of the auditory word recognition system in reaching it, while the other route processes information by means of the visual word recognition system (McShane, 1991, p.289). Considerable evidence has accumulated in recent times

from studies of acquired dyslexia and children with reading difficulties that the phonological route is extremely important in the development of good reading. In his examination of the available evidence on this topic, McShane commented (ibid., pp. 309, 310):

> It would seem then that a sensitivity to the sound structure of language is an important determinant of reading ability. The process of learning to read probably increases this sensitivity and may create an increasing gap in reading ability between children who have difficulty in representing the sound structure of the language and those who do not.... Any underlying delay or inability to create phonological representations will obviously hamper the further development of the phonological awareness of language. As has been observed previously, the use of the phonological route is a crucial part of being a skilled reader because it allows unfamiliar words to be read by working out their sound structure.

So, if for second language learners in immersion situations there is suppression of the auditory system initiated by an increased reliance on visual processing, and especially if this develops into an information processing bias, these learners will probably experience difficulties in learning to read, and, given the dependence of most subject areas on being able to read well, they would be unlikely to achieve adequately academically. Once again the question that must be asked is: Is there any evidence of particular reading difficulty in second language learners?

It is of interest to note in this respect that, in the analysis of academic achievement results conducted by Collier (1987) which showed high math achievement by ESL students, another consistent pattern across all grades was that reading scores were the lowest of all subject matters even after four to five years of residence in the country, and were well below school system means. Since it has also been shown that increasing phonological awareness in children does improve reading performance (See McShane, 1990, p. 306), at least one route to better performance is sign-posted. Hence knowledge of where the difficulty inside the brain might lie may point the way to remediation. Let me hasten to add at this point, that I am not suggesting that **all** difficulties in achieving academically have their source in language. What I am saying is that **if they do**, then a neuroscientific perspective can give a clear conception of what to test for.

On the interference effects of sociocultural factors

Obviously, it would be preferable to avoid the development of a long-term shift in learning strategy if at all possible, and it is evident that in some immersion situations, the so-called additive bilingualism situations, this does not occur to any significant degree. What, then, are the crucial differences between these additive situations and the ones in which students experience academic difficulties? One would appear to be the opportunity to communicate in the first language, which is, of course, closely related to the status of the

language in the community. In the case of majority second language learners such as those in the St. Lambert Experiment conducted by Lambert and Tucker (1972), the prevalence of their first language in interactions of all kinds outside school would tend to counterbalance the swing towards visual processing which would automatically be initiated during class time. For the minority student, however, the opportunity to communicate in the first language would be relatively small compared to the majority student, and furthermore, the lack of importance or meaningfulness accorded to the language by the larger community would also promote the allocation of attention towards the learning and use of the second, more socially meaningful language rather than the first. Remember here that meaningfulness is bred out of familiarity, and that familiarity is based on learning or experience. What I am suggesting, therefore is that the learning of the high value of the majority language coupled with the lack of worth of their first language which would be absorbed through myriad societal interactions, including educational, is "inside the head" of these minority students in a very real way, and causes them to turn their attention away from the learning of their own first language. Both these factors, then, would consolidate the tendency to process information preferentially via the visual system. Thus, for these minority language students, it would seem particularly important for the school system to promote the upkeep of the first language and culture as a general ploy for tempering or even preventing a long-term shift in information processing strategy.

Corroboration of the wisdom of this approach can be found in the academic success of the private bilingual Cuban ethnic schools in Dade County, Florida. Garcia and Otheguy (1985) found that, as well as employing "**very** extensive use of Spanish" (p. 11), "these schools provide continuity between the home and the school by recognizing and respecting not only the child's language but also, most importantly, the parent's culture and behavioural norms. What these schools 'sell' to parents, then, is a sound and **familiar** education" (p. 12). From the neuroscientific perspective, this would indeed appear to be a sound plan, since the abundance of familiar input and the evident emphasis on the worth of the language and culture would not only enable the children to process much of the information via the low attention demanding route, freeing up the capacity limited attention route for the processing of educationally relevant material, but also predispose them to allocate attention to the learning of their own language while also learning English, thereby reducing the probability of an attentional swing to the visual system.

Concluding remarks

It should be abundantly clear by now that I am strongly in favour of incorporating the information emerging from neuroscientific research, as well from the affiliated disciplines of cognitive psychology and artificial intelligence, into educational thinking on recalcitrant problems such as how to explain the underlying causes of difficulties in academic achievement experienced by second language learners. The benefits of doing so are several: firstly, advantage can be taken of the vast stores of studies carried out in these areas; secondly, the degree of resolution of the information obtained is much finer than in

much second language research, and therefore the analytical insight gained from it is more precise; and thirdly, the perspective gained is "brain-oriented". In other words, rather than simply observing behaviour and extrapolating from this behaviour explanatory mechanisms which may or may not reflect biological processes, theories can be constructed bottom-up from data on the inner workings of the brain. Thus the priorities of the brain itself, which are constrained by its neuronal and systemic architecture, can be taken into account in theorising, and checked against the top-down observations carried out in educational research circles. In this way, a more highly-informed approach to educational problem solving would be promoted.

Finally, what the neuroscientific perspective on brain processing accomplishes is the dissolving of artificially constructed differences which appear to have a life of their own, but which are in actuality only dimensions of an underlying reality. Thus, the multiplicity of variables which have been identified as important in producing the results in academic achievement observed for second language learners, linguistic, educational, sociocultural, political factors, and so on, are merely various dimensions of informational input to the brain, all having their effect, all having their importance, and all being computed and integrated to form a coherent system of beliefs. The time has come, I believe, for such a non-partisan perspective to inform educational theorising.

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Notes

[1] *The references given here represent only a sampling of the many available in which the topics raised are dealt with to a greater or lesser degree.*

[2] *Strictly speaking, the Threshold Hypothesis is incorrectly categorised as an hypothesis since it would be extremely difficult to prove empirically, a point which Cummins has recently conceded (Cummins, 1991, p. 83). Cummins has referred on several occasions to its "heuristic function", and it is indeed more adequately characterised as an heuristic.*

[3] *It should be noted, however, that Diaz subsequently discussed the implications of the relationships between degree of bilingualism and cognitive variance as if they had*

attained significance and even proposed a new threshold hypothesis on the basis of his results.

[4] *At a recent conference of cognitive psychologists working in the field of attention, the West Coast Attention Conference in Eugene, Oregon (1993), when I asked some participants to define "attention" and "cognition", my request met with tremendous reluctance on the part of most of those gathered to commit themselves to any single definition, or even to any definition, due to the lack of consensus amongst them on the defining characteristics of these constructs. Only one person, a neuroscientist, ventured a definition of attention, and, naturally enough, the explanation he gave was geared to the neuronal level of resolution.*

[5] *The models can only be considered to exhibit a measure of biological validity in terms of the manner in which the units are connected to one another.*

[6] *This is more correctly termed the cell at the postsynaptic site of the incoming synaptic signals.*

[7] *Direct quote taken at the West Coast Attention Conference, Eugene, Oregon, May, 1993.*

[8] *There was a general consensus among many of the researchers at the West Coast Attention conference on this point.*

[9] *In a personal communication, Steve Petersen of Washington University commented that, based on conclusions from one particular experiment, if subjects are given "ambiguous instructions as to how to do the task, a subject's history could tip the balance in the [information processing] strategy that he or she adopted." He was referring at this time to the activation of one area of the brain over another, which would involve directing attention to the area selected. Furthermore, while musing on the best way to define a visual "feature", one of the most elementary building blocks of the visual system, Anne Treisman suggested that "they may be 'hard-wired' into the structure of the visual system, either innately or through early or prolonged experience." (Treisman, 1988, p. 230) Hence even the involuntary allocation of attention may depend on experience.*

[10] *It should be noted, however, that in an early paper (Treisman, 1964), Anne Treisman used the terms familiarity and meaningfulness interchangeably: "The familiarity or meaningfulness to the S [subject] of the foreign language did affect the degree of interference it produced" (p. 211). Employed in this manner, I believe "meaningfulness" refers more to "fullness of meaning" rather than value or importance.*

[11] *Having examined this test closely, it is still unclear to me how a verbal/analytic approach might work. Reynolds also notes that the "differences in perceptual style" can affect results (p. 161).*
However, the matrices are presented visually and so visual perceptual processing must be

involved to a large degree.

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